Fire History of the Lamar River Drainage
Yellowstone National Park, Wyoming

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Systems for Environmental Mgt
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FIRE HISTORY OF THE LAMAR RIVER DRAINAGE, YELLOWSTONE NATIONAL PARK, WYOMING

PHASE I: Cache Creek Study Area

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INTRODUCTION

This study represents phase I of a multi-year effort documenting fire history of the upper Lamar River drainage in northeastern Yellowstone National Park (YNP). Patterns of fire history and post-fire succession are being studied to provide baseline data for natural fire management, helping managers determine appropriate fire management strategies for YNP. Fire history has been documented elsewhere in the park (Houston 1973, Romme 1982, Romme and Despain 1989), for example, Romme (1982) and Romme and Despain (1989) found that very long-interval stand replacing fires were characteristic in lodgepole pine (_Pinus contorta_ var. _latifolia_) forests on the Quaternary rhyolitic geologic types. No fire regime information existed for lodgepole pine forests occupying Lower Tertiary geologic types (largely andesite) that occur in much of eastern and northern YNP, including the Lamar River drainage. This study was especially timely because much of the Lamar drainage was burned by the 1988 fires (Fig. 1) and historical tree ring data soon will be lost due to weathering and decay of potential sample trees.

The study's objectives are to: 1) Determine pre-1900 fire periodicities, severities, burning patterns, and post-fire succession within the study area's major forest types; 2) document and map the pre-burn 1988 forest age class mosaic; and 3) digitize the age class mosaic map for inclusion into the park's GIS data base.

STUDY AREA

The entire study area encompasses the Lamar River drainage southeast of Soda Butte Creek in the Absaroka Mountains (Fig. 1). A representative ~24,000 ha area encompassing the Cache Creek drainage was selected for phase I of the study (Fig. 2). This area is bounded on the northwest and north by Soda Butte Creek and Ampitheater Creek, on the northeast and east by the Absaroka divide, on the south by the Calfee Creek divide, and on the west by the Lamar River.

Before the widespread stand replacing fires of 1988 (Clover-Mist Fire), much of the area was occupied by lodgepole pine dominated forests. (Throughout YNP extensive even-age classes of lodgepole pine have regenerated shortly after stand replacing fires that exposed mineral soil seedbeds and released seeds from serotinous cones [Taylor 1974]). The study area's forests are more moist and productive than those on YNP's rhyolitic central plateau due to the more nutrient-rich andesitic soils and increasing precipitation from the Pacific maritime storm track near high mountain divides (Steele et al. 1983).

Nearly 70% of the study area (~16,800 ha) is occupied by rocklands and "non-fire generated" (uneven age) stands--south slope grasslands, dry Douglas-fir stands, and high elevation whitebark pine (Pinus albicaulis) stands--with the remainder (~7200 ha) occupied by fire initiated (even age) lodgepole pine stands. The northwest portion of the study area contains the uppermost extension of high elevation (~2000 m) Artemisia/bunchgrass types within the broad Lamar River Valley, reflecting the dry continental precipitation regime typical of YNP's lower elevations (Steele et al. 1983). At the forest/grassland ecotone, uneven-aged Douglas-fir (Pseudotsuga menziesii var. glauca) stands with understories of bunchgrass and scattered low shrubs occupy south slopes to moderately high elevations (2000-2500 m). The study area's steep mountain terrain is dissected by dendritic stream canyons often headed by alpine glacial troughs near the Absaroka Divide (~3200 m). Pre-1988 lodgepole pine- or whitebark pine dominated stands extended to ~2900 m, with understories of the shade tolerant subalpine fir (Abies lasiocarpa) and Engelmann spruce (Picea engelmannii). The study area's major forest habitat types (Steele et al. 1983) are: 1) P. menziesii/Calamagrostis rubescens and /Symphorocarpus albus along the grassland/forest ecotone, 2) P. engelmannii/Linnea borealis and A. lasiocarpa/Vaccinium globulare in moist draws and sheltered north slopes at low- to mid elevations, 3) A. lasiocarpa/Vaccinium scoparium on most well

drained aspects at mid- to upper elevations, and 4) P. albicaulis/V. scoparium and /Carex rossii on exposed upper elevation ridges.

METHODS

Samples from fire-initiated seral age classes (primarily lodgepole pine) and basal fire scars were used to document fire history. Old Douglas-firs with multiple scars from past fires are relatively abundant along the grassland/forest ecotone (Houston 1973), allowing fire years to be estimated from sawn cross-sections (Arno and Sneck 1977). Fire scars were less common in the adjacent lodgepole pine forests so fire years were estimated from increment cores of fire-initiated seral age classes, then the data were used to develop maps of the pre-1988 forest age class mosaic (Heinselman 1977, Tande 1979, Romme 1982, Barrett and Arno 1988, Romme and Despain 1989).

In the office, an acetate overlay of a 1:62,500 forest cover type map developed by Despain (1986) was used to transfer different-age stands to topographic maps for field use. The cover type map displayed the study area's pre-1988 successional stages according to the following classification (Despain 1986): 1) LP0 (recently fire-initiated stand: 0-40 yr old), 2) LP1 (large sapling small pole: 40-100 yr old), 3) LP2 (mature: 100 to 300 yr old), 4) LP3 (overmature/lodgepole pine dominated: 300+ yr), 5) LP4 (overmature/mixed dominants lodgepole pine/subalpine fir), 6) WB 0-4 (same age sequence for whitebark pine), and 7) DF 0-4 (same age sequence for Douglas-fir). Sample transects were chosen by marking trails and ridge systems that cross representative terrain. Potential sample sites also were pre-selected by delineating stands within evidently different aged fire-initiated age classes (Heinselman 1973, Tande 1979, Romme 1982, Barrett and Arno 1988).

In the field, as a new stand was encountered along a transect the stand-initiation year was estimated by increment boring dominant seral trees within 30 cm of ground surface (Barrett and Arno 1988). In YNP large numbers of

lodgepole pine usually become established within a few years after stand replacing fires (Taylor 1974, Romme 1982, Despain and Romme 1989). Therefore, when no fire scar sample was available, the fire year was estimated by using the earliest establishment year among several similarly-aged seral trees in a given fire-initiated age class. Preliminary counts of annual growth rings were made in the field to ensure that similar establishment years (20 yr range) were obtained from at least three seral trees per class.

To document postfire succession, tree composition and age structure was inventoried in each sample stand by establishing from one to three representative circular macroplots (375 m^2), depending upon stand extent and variability (Arno and Sneck 1977, Pfister and Arno 1980). Percent canopy coverages were estimated for each tree species in 4 size classes: saplings (0-10 cm in diameter 1.3 m above ground), poles (10-30 cm), mature trees (30-76 cm), and old growth (>76 cm). It was necessary to reconstruct canopy coverages in 1988-burned stands so tree crown habit and bark traits (e.g. texture, thickness, color) were used as diagnostics for mature trees. Understory vegetation often had been incinerated, therefore unburned stands were relied upon to portray representative understory composition and habitat types. Finally, 2 or more of the largest diameter shade-tolerant trees in each size class were sampled to augment the stand structure data already obtained from seral age classes.

In the office, fire scar years were estimated by sanding and dating sawn fire scar cross sections under magnification (Arno and Sneck 1977). The age-class increment cores were sanded and the annual growth rings were counted from the appropriate cambium year (1988 or 1989). For cores that missed the pith, a small number of years was added to obtain the approximate total tree age (Arno and Sneck 1977). The final estimate of a given stand initiation year (approx. fire year) was made using the following criteria: similar tree-establishment

years (within a range of 20 yr) were necessary for at least three seral trees and, in the absence of datable fire scars or fire atlas records, the stand initiation year was considered to be the earliest among a group of similarly aged seral trees.

Despain's (1986) cover type map was edited by first labelling the stand initiation years at the sample stand locations. Stereo photointerpretation of 1:20,000 aerial photographs, in tandem with the age class- and fire scar data, was used to draw the margins of any stands not shown on Despain's (1986) map. Tree crown texture, tone, relative height, and relative diameter were used as indices of relative stand age, thus known age classes were extrapolated to any nearby unvisited stands with similar canopies. When extrapolation was not possible, relative age labels (e.g. "pre-1850) were assigned to the unvisited stands by comparing their canopy traits to those of sampled stands.

To supplement YNP's Geographic Information System, the edited forest age class map was digitized in UNIX compatible format for use with SAGIS and GRASS software. The study area's topographic maps were edge-matched so that polygon boundaries leaving one map would start on the adjoining map at the same location, and all polygons were closed off and labelled according to the estimated stand initiation years or the relative age labels. The maps were digitized on a Calcomp 9100 digitizer connected to a Sun 386i micro-computer using ARC/INFO software (map coordinates were input in the UTM coordinate system). Each map was plotted at 1:62,500 scale after initial digitizing, and was checked for errors against the original age class maps. Errors were corrected and the final plots were created at the 1:62,500 scale. Each file was exported to create a standard flat file of vector coordinates, followed by creation of Raster format files.

Two methods were used to calculate fire frequency. A master fire chronology (Arno and Sneck 1977, Romme 1980) was compiled for each sample stand containing

fire scarred trees by listing the estimated years of all fires. Mean fire intervals (MFIs) for stands and for the entire study area were calculated by dividing the time period between the first and last fires by the number of intervals. If stands in a given forest type typically produced evidence of only one fire interval per stand, Barrett and Arno's (1988) method was used whereby fire frequency was estimated by determining a multiple site average fire interval (MAFI). MAFI is the mean of the single fire intervals determined from a network of stands occupying similar habitat types.

Postfire tree succession was examined by graphing canopy coverages of each tree species by the four sampled size classes and labelling the ages sampled from each class. Successional interpretations were made by examining each stand's structure and age patterns relative to its fire history.

RESULTS AND DISCUSSION

Fire Patterns. Nine transects, covering ~85 km, produced 182 increment cores from fire initiated seral age classes at 43 sample sites (Fig. 3). These age class data were supplemented by fire scar samples from 17 trees (8 from sawn cross sections, 9 from increment cores [Barrett and Arno 1988]). Fire history interpretations are based on these samples in tandem with the forest age class map, as well as associated tree inventory plots portraying post-fire succession in the 43 stands.

The aerial photographs and age class data showing sample stand locations suggested that little editing of Despain's (1986) map was necessary. Most stand margins on the original map had been depicted as accurately as possible, especially given the fact that only a few decades often separated the ages of adjacent old stands. Because it frequently was not possible to distinguish between the margins of adjacent mature stands the stands were grouped into one polygon and labelled according the best age estimate from nearby samples.

There were only 2 substantive findings from the map editing: 1) the specific stand initiation years were labelled where possible, and 2) Despain's (1986) map depicted successional stages ranging from LP2 (100-300 yr) to LP4 (300+ yr), whereas the sample stand data indicated that most of the pre-1988 mosaic consisted of age classes between 120 and 230 years old (LP2 classification).

The Cache Creek Master Fire Chronology, representing stand replacing fires that produced the pre-1988 mosaic, extends back to the mid-1700s. Few data predate that time because a large fire in ~1756, and 8 subsequent stand replacing fires up to ~1891, obliterated most evidence of earlier age classes. Therefore the study area Master Fire Chronology spans 233 years between ~1756 and 1989. (Additionally, fires scars on 6 Douglas-firs and 2 lodgepole pines from 4 stands in the grassland/forest ecotone provided a relatively continuous record of non-lethal surface fires back to ~1534). Age class sampling produced evidence of 11 stand replacing fires during the 233 year period, and 10 fires produced the pre-1988 forest age class mosaic (Table 1, Fig. 4). These data yield a mean fire interval (MFI) of 23 years for the entire study area. That is, a stand replacing fire occurred somewhere in the ~24,000 ha study area on an average of every 23 years. Large fires, ones that replaced at least 400 ha within the study area's lodgepole pine age classes, occurred as many as 7 times during the period, yielding an MFI of 39 years for such fires. The data thus suggest that at least 64% of all fires grew to large size.

Major fires (1200+ ha) occurred 3 times, in ~1756, ~1835, and 1988, for a major-fire MFI of 117 years (Table 1, Figs. 4, 5). Thus intervals of only 79 years and 153 years separated these major events in the study area. The 1988 firestorm did not cross the divide between Cache Creek and Soda Butte Creek but it burned virtually the entire Cache Creek drainage, replacing ~60% of the study area's ~7200 ha of even-age lodgepole pine classes, as well as most high elevation (largely uneven age) whitebark pine stands. In examining the 1988

stand replacement patterns, virtually all stands, regardless of successional age class (Despain 1986), were killed in just a few broad stand replacing runs covering several km or more. This contrasts with the complex mosaic pattern that was produced by fires that occurred after the evidently widespread ~1756 fire (Figs. 4, 5). Sampling produced evidence of a small (12 ha) burn in upper Cache Creek in ~1912 (undocumented in the YNP fire atlas) and this was the only other stand replacing fire in this century. (In 1940 a 186 ha human-caused fire was suppressed on the lower Soda Butte Creek grassland and did not burn adjacent forest [unpub. reports on file: YNP Fire Cache]).

Data from widely dispersed sample stands suggest that a relatively large fire occurred in the study area in ~1835 (Figs. 4, 5), and this age class occupied at least 1457 ha (20%) of the pre-1988 lodgepole pine age classes. Unlike the 1988 burning pattern, the age class map suggests that the largest stand polygons attributable to the ~1835 fire did not exceed 500 ha (Fig. 4). However, the ~1756 fire may have been similar in scope to the 1988 fire. Despite the subsequent occurrence of 8 stand replacing fires until ~1891 the 1756 age class still occupied at least 1619 ha (23%) of the pre-1988 lodgepole pine mosaic, in widely dispersed stand polygons (Figs. 4, 5).

Fire Regimes. The data suggest that study area forests experienced several fire regimes, initially apparent by the diverse cover types, and best reflected at the stand level by fire frequencies and post-fire succession. At the edge of valley- and south slope grasslands, dry Douglas-fir stands are uneven-aged and dominated by 300-500 year old Douglas-firs (Houston 1973). These very open stands experienced frequent surface fires, which probably often originated in the grasslands, and consumed small understory trees without killing most mature Douglas-firs (fig. 6). Some old stands were killed during the 1988 fires, undoubtedly a rare occurrence. Old Douglas-firs sometimes have 6 or more fire scars, and samples from 8 trees in a 4-stand cluster suggested 15 fires between

~1534 and 1989--MFI was 32 years and intervals between the fires ranged from ~4-89 years (Table 2). Only one stand had fires in this century (1940, 1988), otherwise the remaining 3 stands had not burned for ~119 years, an unusually long fire interval for such dry stands (Houston 1973, Arno 1980, Arno and Gruell 1986) and a likely result of efficient fire suppression in YNP's northern range (Houston 1973). Douglas-fir stands adjacent to moderately moist sites now have relatively dense understories representing "ladder fuels" into the canopy (Houston 1973, Arno and Gruell 1986)--enhancing the spread of stand replacing fires such as 1988.

Different fire patterns occurred in the adjacent lodgepole pine forests. The 1988 firestorm killed most lodgepole pine- and whitebark pine stands in Cache Creek drainage, but the data suggest that previous fires ranged in severity from moderate to severe, influenced in part by site type and stand fuels. Fire frequencies and severities were found to differ by aspect (Table 3). Relatively moist north slope stands (cool-moist spruce- and subalpine fir habitat types) experienced predominantly infrequent stand replacing fires at ~150-250 year intervals (8-stand MAFI: 202 yr). The stand structure data show that moist-site stands nearly always had a one-aged seral component and lacked fire scarred trees, suggesting that total stand replacing fires prevailed (Fig. 7).

A somewhat different pattern was found in stands on south aspects (warm-dry subalpine fir- and whitebark pine habitat types). Intervals between total stand replacing fires were similar (10-stand MAFI: 178 yr), only slightly shorter than those on moist aspects because one ~76 year old sample stand had burned in 1988 (Table 3). However, dry-site dominants sometimes had single basal fire scars and the associated stand structures sometimes showed a 2-age seral component (Fig. 8), indicating that partial stand replacing fires (patchy lethal surface fires) had occurred in these stands. The sampling occasionally

might have encountered adjacent burn margins but the zone of overlap in such cases usually is very narrow, whereas some stands clearly experienced partial stand replacing fires over a considerable area. Five different-age stands (Table 3) contained fire scarred trees and associated seral regeneration for several km of sampling transect. Such short-interval fires apparently killed as many as half of the stand dominants and triggered a new seral age class (Fig. 8), primarily in canyon bottoms and gently sloped intermediate elevation stands ~20-80 years after stand initiation (5-stand MAFI: 52 yr)(Table 3). This evidence suggests that "reburns" occurred in the post-fire fuels that accumulated after an initial stand replacing fire.

Results to date indicate that lodgepole pine fire regimes in the upper Lamar drainage differ substantially from those on the park's central plateau. Romme's (1982) study of lodgepole pine on high plateaus hypothesized that the combined effects unproductive stands (sparse live fuels), very slow fuel accretion (dead fuels), and gentle terrain often discourages fire spread and results in very long intervals (~300-400 yr) between stand replacing fires. By comparison, stands in the Cache Creek study area occupy more-productive sites (better developed understory fuels) on steeper terrain, where south slope fuels are more prone to drying and where fuel pre-heating occurs more readily during fires. Despain's (1986) description of fire behavior potential for the various lodgepole pine successional classes suggests that the 100-300 year old LP2 class is transitional between the relatively non-flammable LP1 class and the highly flammable LP4 class. Most pre-1988 stands in the Cache Creek study area were in the LP2 class, ~150-230 years old, and Despain (1986) suggests that modal stands within this class (~200 yr) will burn only during extreme conditions. It is therefore possible that some of the fire intervals in Table 3 are uncharacteristically short because the unusually severe 1988 fire (Romme and Despain 1989) provided the only complete fire intervals in the data. (It

was not possible to develop age class chronologies revealing past intervals [Barrett and Arno 1988] because veterans of successive stand replacing fires were not found in the pre-1988 mosaic). Several factors, however, suggest that a ~150-250 year interval range is in fact characteristic: 1) the lodgepole pine mosaic contained virtually no stands older than 250 years, and older age classes would exist if the area had experienced very long fire intervals, 2) the 1988 fire evidently was not unprecendented because evidence of another extensive fire (~1756) occurs in the data, and 3) the Cache Creek fire intervals are similar to those found by other studies of lodgepole pine in mountainous terrain (Arno 1980, Barrett et al. [in prep]). Moreover, fire frequencies also actually may have been lengthened somewhat by fire suppression because the study area is adjacent to the Lamar Valley grassland where many ignitions have been suppressed since the late 1880s (Houston 1973, unpub. reports on file: YNP Fire Cache). Hopefully, future phases of this study (1990, 1991) will detect evidence of complete fire intervals not involving the 1988 fires.

Sampling in the upper subalpine zone produced evidence of multiple surface fires in krummholz stands dominated by old whitebark pine (Fig. 9). Data from 2 stands near timberline (2900 m) suggest that whitebark pines often are 400+ years old and often have from 2-4 fire scars each. Age structures were complex, evidently varying by site type, fire occurrence, epidsodic germination from animal seed caches, and other factors (Arno and Hoff 1989). Increment cores suggest that the stands contained a mix of uneven aged whitebark pine and subalpine fir, and 2 or more even aged groups of pines that evidently regenerated after fires. One stand near Republic Pass had 450+ year old pines with 2-4 fire scars each and yielded a stand MFI of 83 years for non-lethal surface fires. Even during the severe 1988 fires, timberline stands often experienced only non-lethal- or partial stand replacing fire. Because of the

complex age structures it was not possible to obtain detailed information on stand replacing fire intervals in the upper subalpine zone. Arno (1980) and Fischer and Clayton (1983) suggest that factors such as infrequent drought, sparse fuels, rocky terrain, and recurring patchy surface fires encourages very long intervals between stand replacing fires (400+ yr). Fischer and Clayton (1983) point out, however, that such statistics are difficult to interpret--the concept of fire frequency does not apply well near timberline since a fire might involve only one or two trees in a stand.

Effects of Fire Suppression. At least 3 cultural periods occur during the time span of the fire history data (Houston 1973, Taylor 1974, Romme and Despain 1989): 1) the Prehistoric Period (pre-1886), 2) Complete Suppression Policy (1886-1976), and 3) the Natural Fire Program (1976 to present). Fire suppression was effective in remote areas for only about 30 years before the natural fire program (Romme and Despain 1989), suggesting a logical fourth category for remote areas between 1945-1976 (Fig. 5). However, since the Cache Creek study area adjoins grasslands where many fires were suppressed after the park's inception (Houston 1973), the 1886-1976 period would best apply to the Phase I study area.

Indians and others undoubtedly contributed to ignition frequency during the Prehistoric Period, particularly in northern YNP's grassland valleys (Houston 1973). For example, Houston (1973) found that Indians inadvertantly caused a major fire in the lower and mid Lamar Valley in 1870--journals mentioned that the fire was ignited to drive game. Interestingly, data for the nearby Cache Creek study area indicate that a ~1870 fire replaced a substantial portion of the area's lodgepole pine age classes (Figs. 4, 5). The Lamar Valley and Soda Butte Creek drainage has been an important travel route for humans since at least the beginning of historical records, and probably for untold centuries before that time. In his famous flight from the U.S. Army in 1888, Nez Perce

Chief Joseph travelled this route over the Absaroka Divide to reach north-central Montana. Miners also prospected the area extensively in the late 1800s, including the Cache Creek drainage, which derives its name from an incident involving miners fleeing from Indians. However, Houston (1973) felt it would be difficult to quantify humans' role in igniting fires during the pre-fire suppression era, particularly in remote areas of the park because there is scant evidence of human use patterns.

Houston's (1973) fire scar data showed a marked decrease in fire frequency on the northern range after the late 1800s, and Houston's (1982) comparison of old photographs with modern retakes found that grasslands and adjacent dry Douglas-fir stands have markedly increased in densities of fire sensitive species. The fire frequency data from dry Douglas-fir stands in the Cache Creek study area agree with Houston's (1973) findings in that a trend toward longer fire intervals began in the late 1800s, suggesting a relatively long period of efficient fire suppression in those areas.

The YNP fire atlas (unpub. reports on file: YNP Fire Cache) also produced evidence of efficient fire suppression, particularly near roads. Fourteen fires were recorded for the study area during the 6-decade period of record between 1930 and 1989--only 2 occurred during the period of the Natural Fire Program (1988 and a 1986 spot fire). The 1988 fire was the only significant stand replacing event during the period of record, and most of the 12 suppressed ignitions were less than a hectare in size. Moreover, 8 (67%) of the 12 suppressed fires occurred on the dry grasslands near Soda Butte Creek, and 3 (38%) of these fires were caused by humans. Several factors suggest that some suppressed fires had potential to become important stand replacing fires: 1) 6 (50%) of the 12 suppressed fires occurred during known drought years (1936, 1940, 1949, 1960)(unpub. reports on file: YNP Fire Atlas, Romme and Despain 1989), 2) most suppressed ignitions occurred in dry grassland fuels

where fires can rapidly become large and spread into adjacent forests, and 3) efficiency of detection and suppression apparently decreased with increasing distance from roads, allowing backcountry fires to spread to substantial size before suppression. Examination of fire reports for the entire Lamar River study area (including drainages southeast of Cache Creek) reveals that 14 of 19 reported ignitions (74%) were within a few km of the Northeast Entrance Road, and 8 (57%) of the 14 fires occurred in the roadside grasslands. Only 5 ignitions were reported for the extensive area southeast of Cache Creek, and 2 of these fires had acheived substantial size (47, 23 ha) before they were suppressed. Without suppression some of these wildfires might well have substantially altered the forest mosaic, thus possibly also influencing the eventual 1988 burn pattern (Romme and Despain 1989).

Romme and Despain (1989) analyzed the relative coverage of Despain's (1986) successional classes (LP1-LP4) in YNP over time and concluded that the 1988 fires were largely a result of severe burning conditions coinciding with aging (fire receptive) stands that blanketed much of the park (fires in the early 1700s had created large expanses of new age classes that theoretically [Romme 1982] would remain unreceptive to stand replacing fires until at least the late 1900s). Since most of the park's lodgepole pine stands occur in remote areas Romme and Despain (1989) felt that fire suppression might have precluded a few stand replacing fires for only several decades before the onset of the natural fire program in the mid-1970s. Mosaic diversity thus was somewhat reduced by fire suppression but, because the severe 1988 fires often burned all age classes in its path, the researchers reasoned that fire suppression's effect on natural fire patterns probably has been minimal.

The hypotheses developed by Romme (1982) and Romme and Despain (1989)-- 1) that lodgepole pine stands become more receptive to fire with advanced stand age, and 2) that the 1988 fires were a largely natural event given YNP's

extensive old age classes--would apply to the Cache Creek study area if the fuel modelling assumptions apply to both rhyolitic plateau- and andesitic mountain terrain, and if fire suppression's role in promoting mosaic homogeneity is discounted. Fire cycle estimates for the lodgepole pine forested portion of the study area suggest a per-century burn rate of 89% for the 1700-1800 period, 39% for the 1800-1900 period, and 67% for this century (Table 1, Fig. 5). Therefore most of the mosaic was in the mid- to late LP2 successional class (150-250 yr) when the 1988 fires occurred. Future phases of this study will provide more data on natural fire regimes for the Lamar River drainage, perhaps allowing a more refined comparison of pre- and post 1900 fire patterns on YNP's andesitic mountain terrain.

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Fig.1

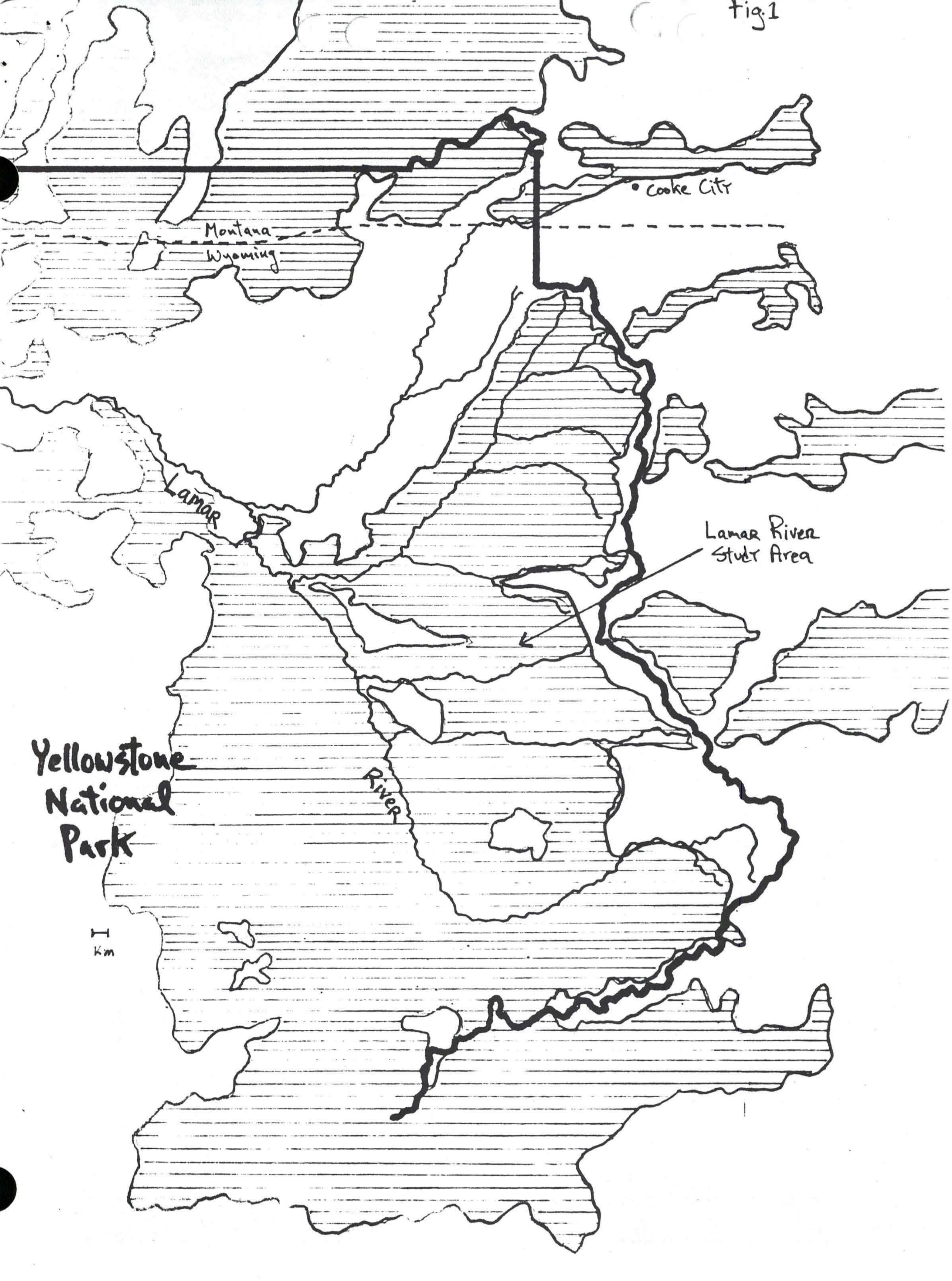
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Fig 2

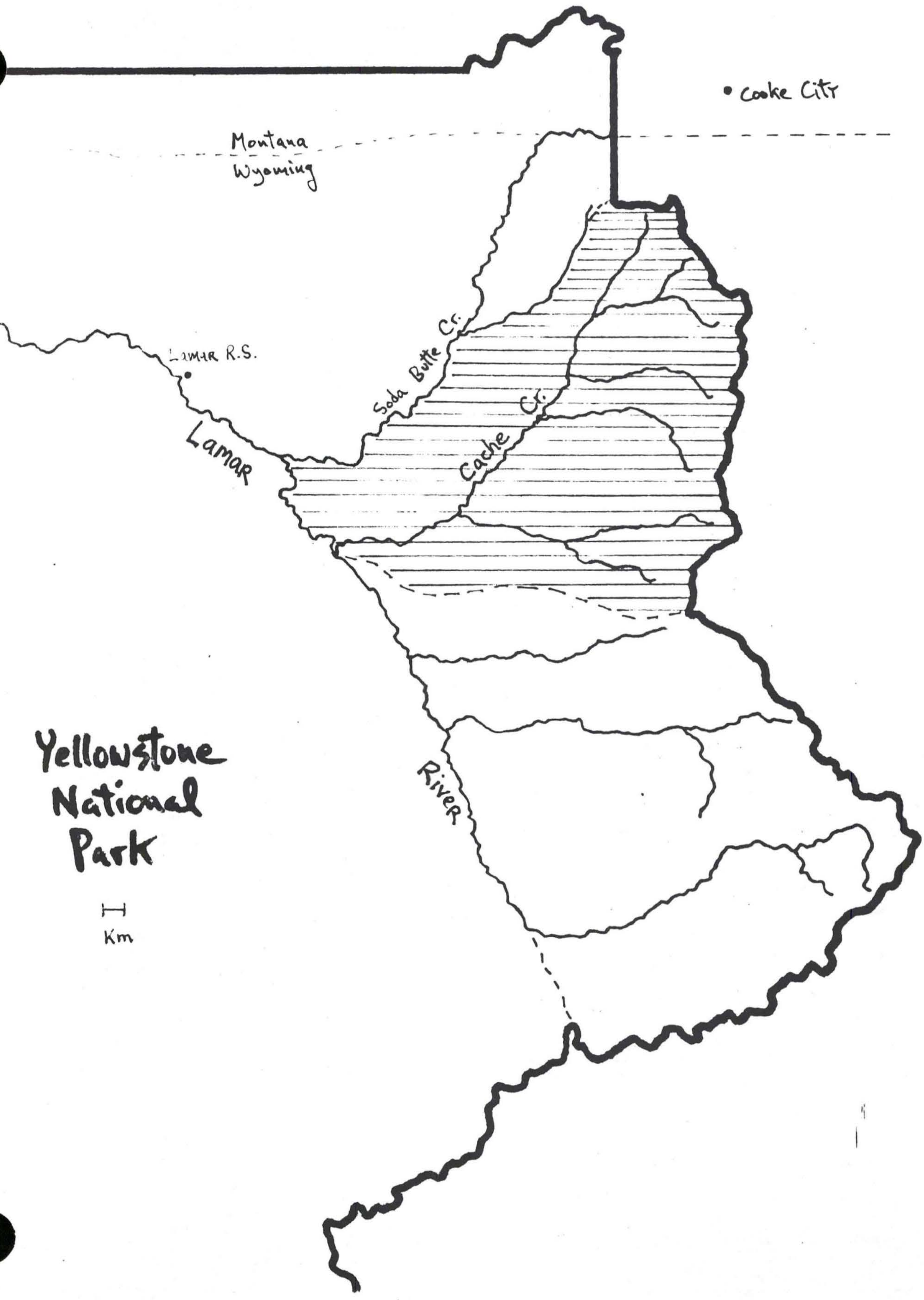

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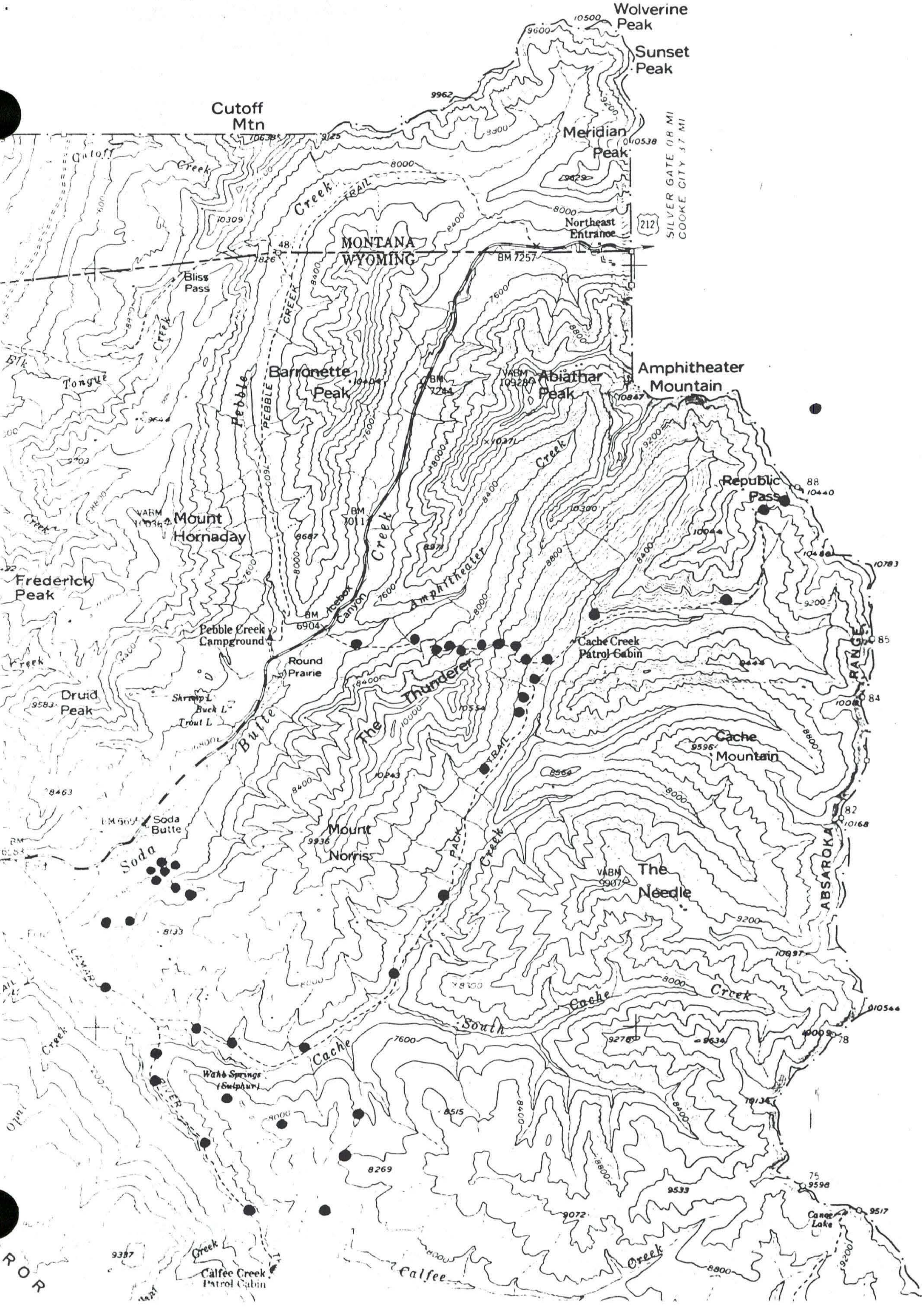
Fig. 3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Bliss Pass
Pebble Creek
PEBBLE CREEK TRAIL
Barronette Peak
Abiathar Peak
Amphitheater Mountain
Amphitheater Creek
Republic Pass
Mount Hornaday
Frederick Peak
Icebox Canyon
Pebble Creek Campground
Round Prairie
Cache Creek Patrol Cabin
The Thunderer
Druid Peak
Shrimp L
Buck L
Trout L
Soda Butte
Cache Mountain
ABSAROKA RANGE
Mount Norris
The Needle
LAMAR RIVER
Cache Creek
South Cache
Wahb Springs (Sulphur)
Calfee Creek Patrol Cabin
Calfee Creek
Canoe Lake
PACK TRAIL

Fig 4

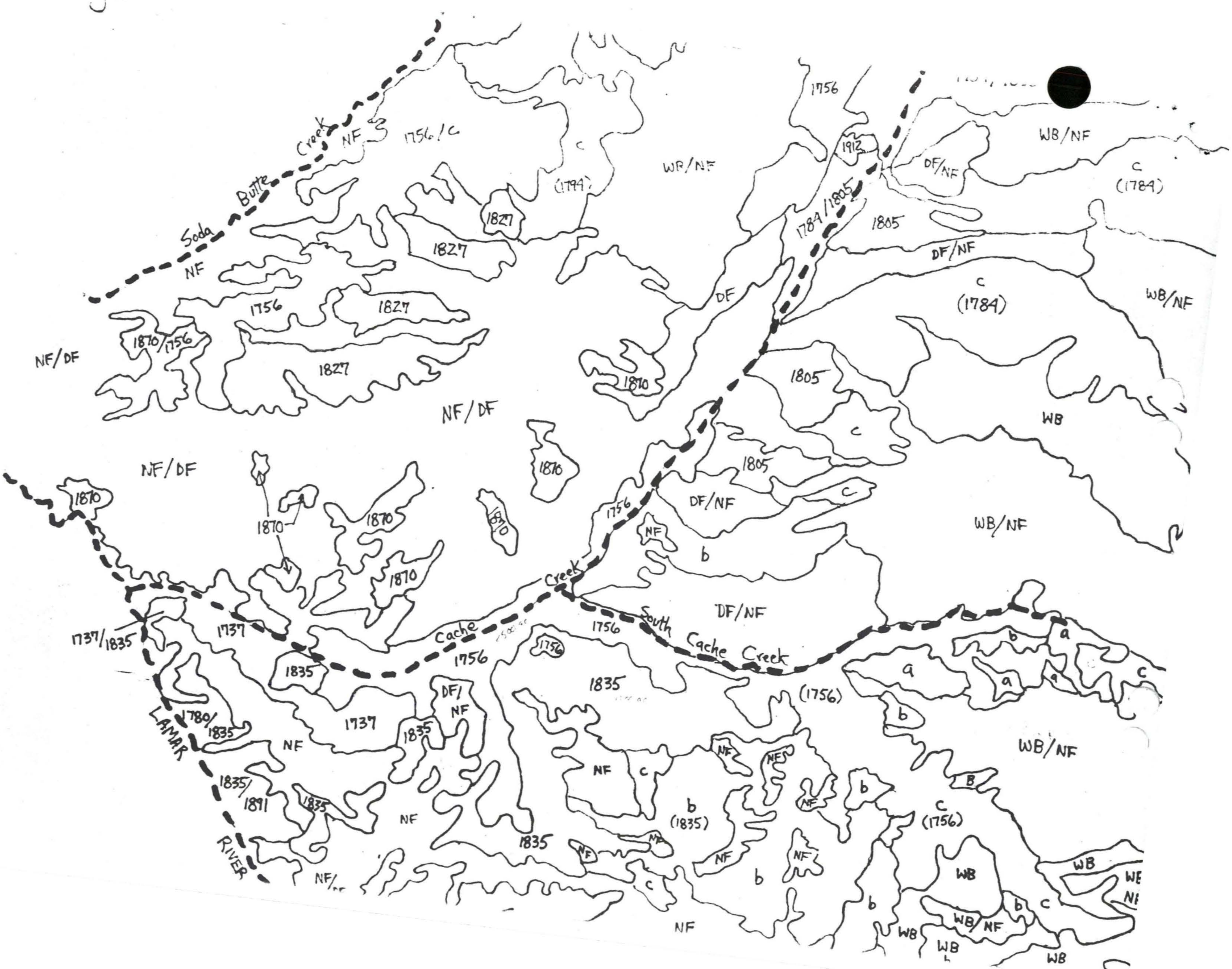

Soda Butte Creek
NF
1756/C
C
(1794)
WF/NF
1756
1912
1784/1805
1805
DF/NF
WB/NF
C
(1784)
1827
1827
1827
1756
1827
1870/1756
NF/DF
NF/DF
NF/DF
DF
C
(1784)
WB/NF
1870
1805
C
WB
1870
1805
DF/NF
C
1870
1870
1870
1870
1870
1756
NF
b
WB/NF
1870
Cache Creek
DF/NF
South Cache Creek
1737/1835
1737
1835
1756
1756
1756
1835
(1756)
a
a
a
a
b
C
1737
DF/NF
1835
1780/1835
NF
b
WB/NF
LAMAR RIVER
NF
C
NF
NF
NF
b
B
1835/1891
1835
NF
b
(1835)
NF
C
(1756)
1835
NF
NF
NF
NF
b
WB
WB
WB/NF
NF/
C
NF
b
C
b
WB
WB
WB

Fig 5. Stand replacing fires according to percent of lodgepole pine forest burned (percent of total lodgepole pine forest burned per century in parentheses).

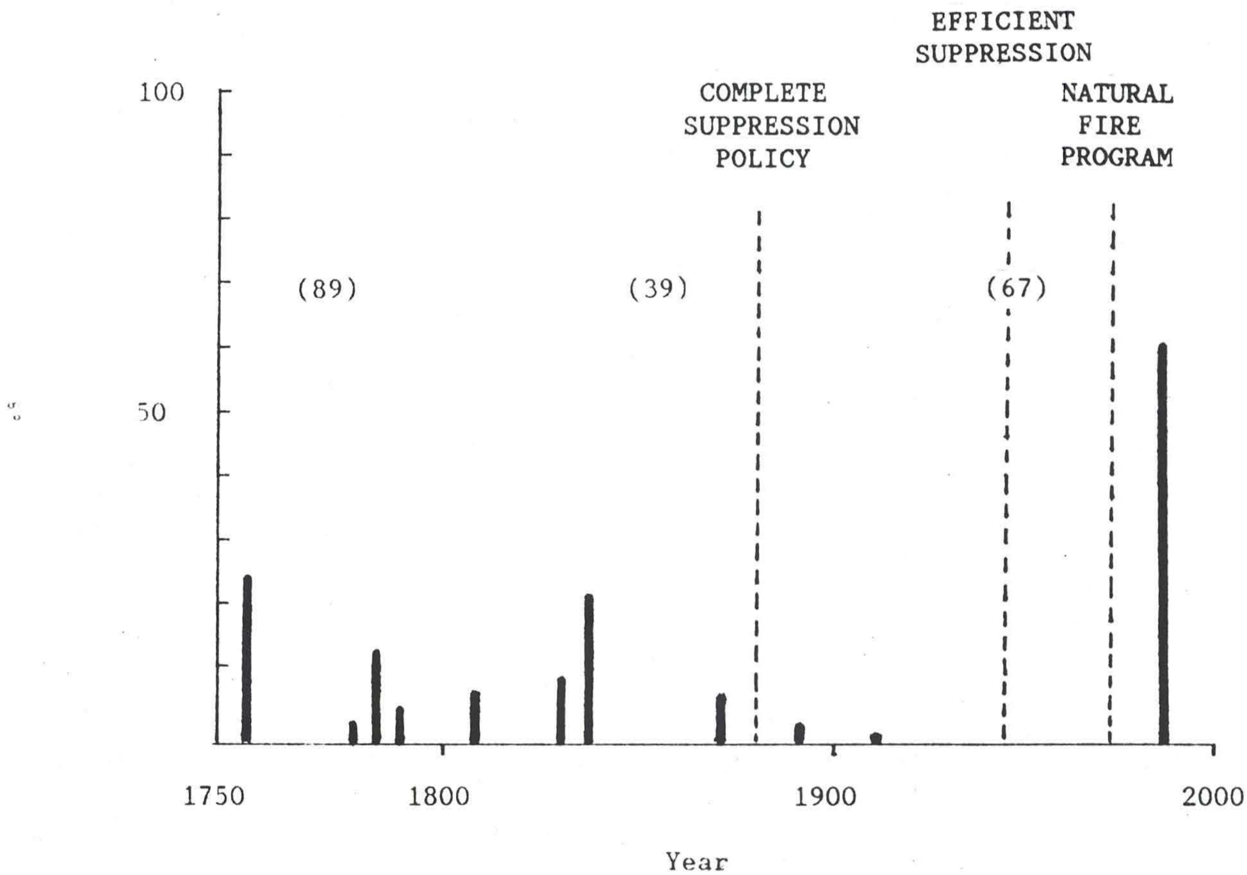
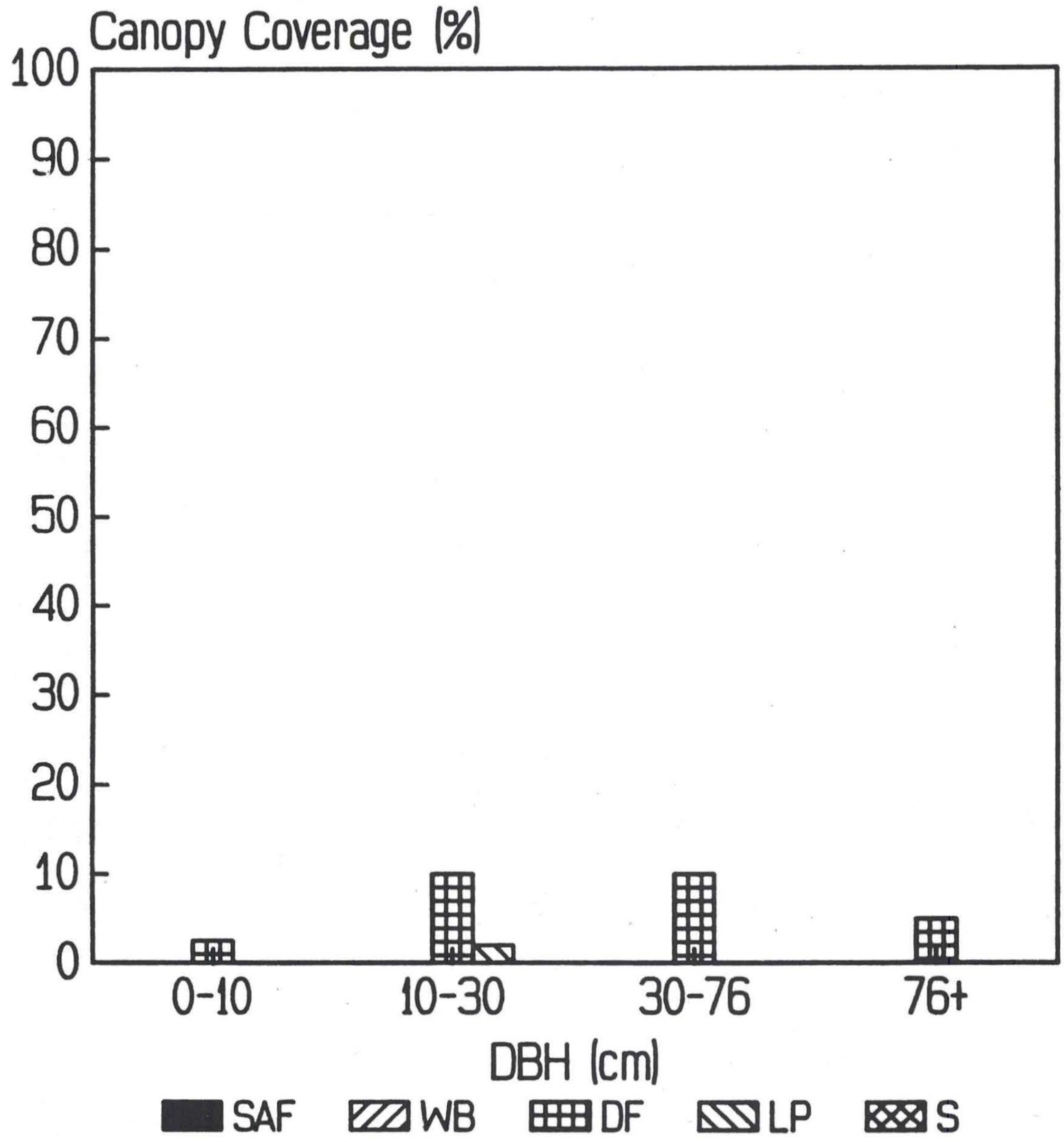
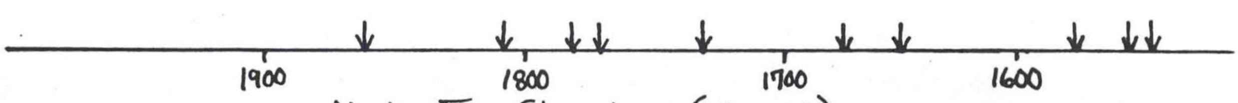


Fig 6

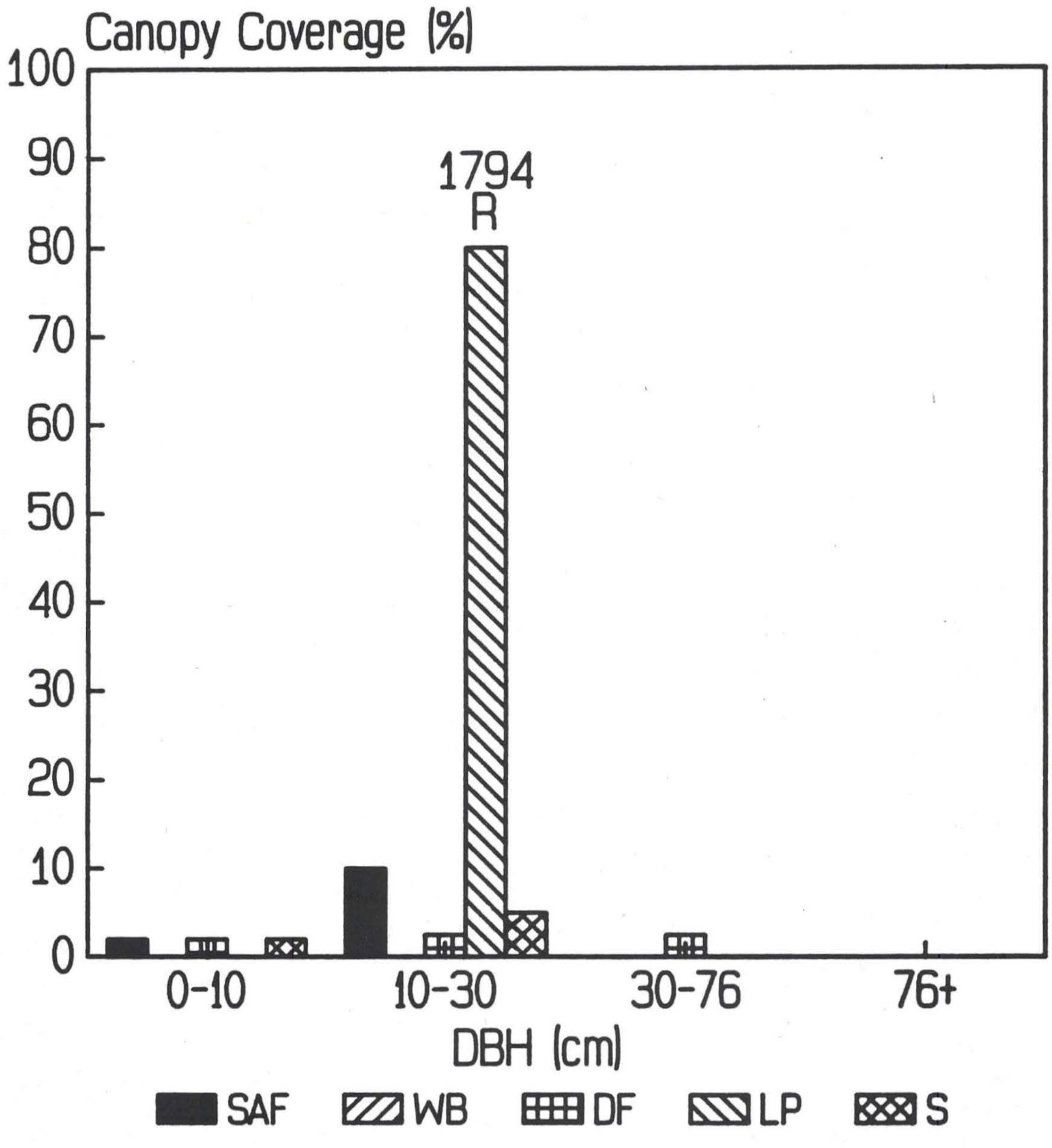
STAND 31



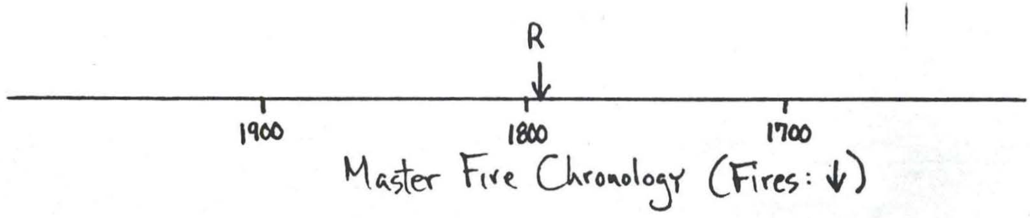


Master Fire Chronology (Fires: ↓)

STAND 2



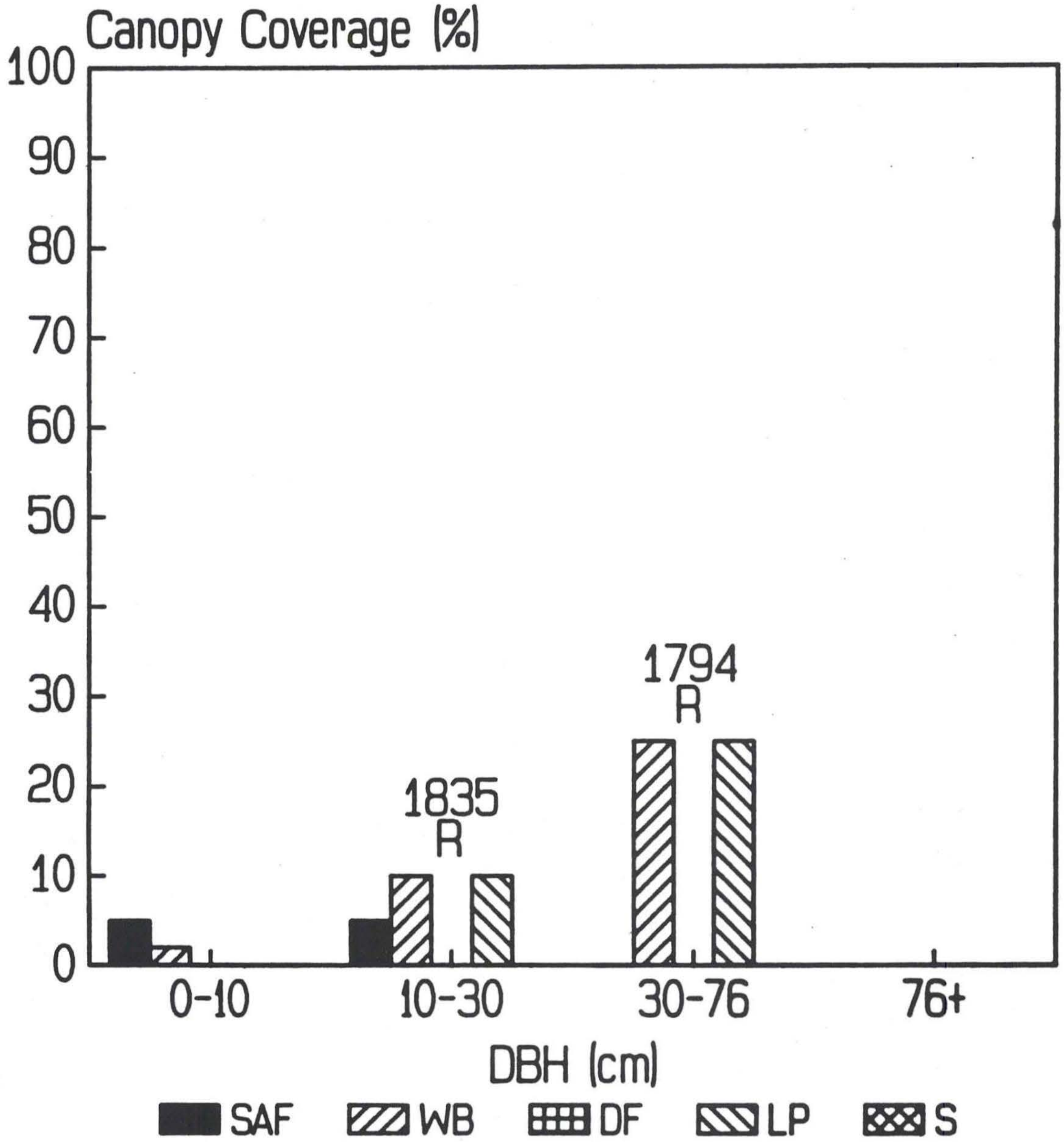
Canopy Coverage (%)
100
90
80
70
60
50
40
30
20
10
0
1794
R
0-10
10-30
30-76
76+
DBH (cm)
SAF
WB
DF
LP
S

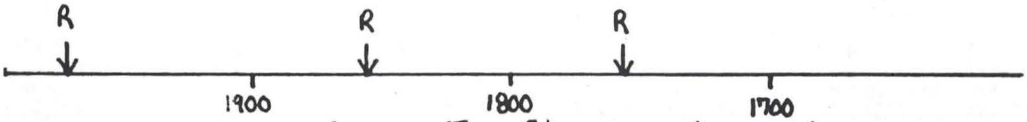


R
1900
1800
1700
Master Fire Chronology (Fires: ↓)

Fig 8

STAND 28

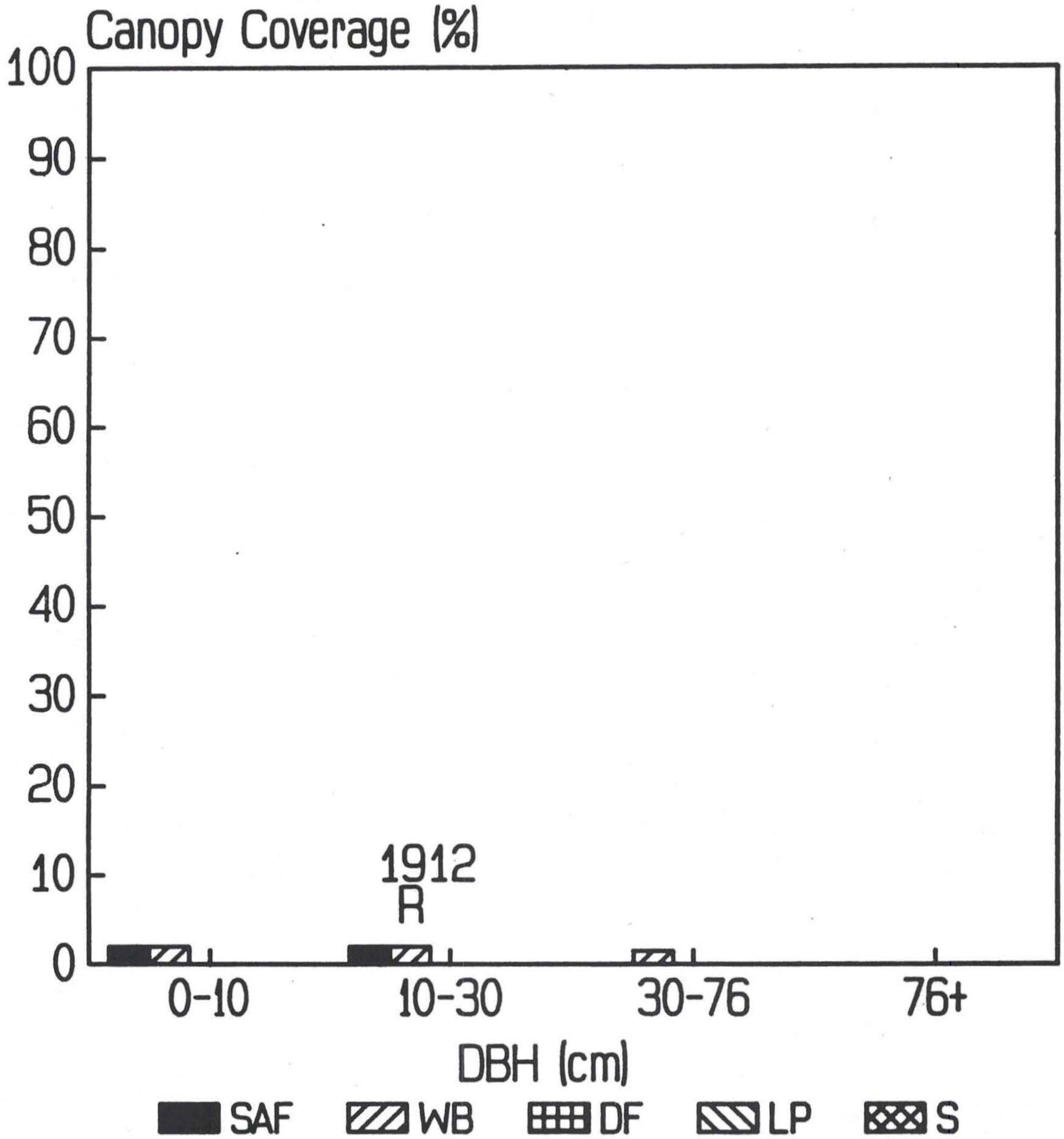


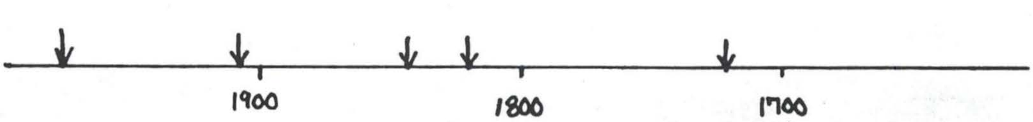


...r Fire Chronology (Fires: ↓)

Fig. 9

STAND 13





Master Fire Chronology (Fires: ↓)

Table 1. Master Fire Chronology for stand replacing fires in the ~7200 ha lodgepole pine forested area between ~1756 and 1989 (numbers of age class samples in parentheses).

Est. Fire Year	Est. Minimum Hectares	% of Area	% of Area Burned Per Century
1756 (48)	1619	23	
1780 (7)	162	2	89
1784 (7)	769	11	
1794 (9)	243	3	
1805 (6)	364	5	
1827 (6)	526	7	
1835 (27)	1457	20	39
1870 (24)	324	5	
1891 (3)	121	2	
1912 (3)	12	<1	
1988 (0)	4320	60	67

MFIs

All Fires: 23 yr
Large Fires (400+ ha): 39 yr
Major Fires (1200+ ha): 117 yr

Interval Range

1756-1989: 8-76 yr
pre-1900: 8-35 yr

Table 2. Fire occurrence data (MFIs based on fire scars) for non-lethal surface fires within Douglas-fir stands along the grassland/forest ecotone.

Stand No.	Hab. Type	No. Trees	Master Fire Chronology (yr)	No. Fires	Interval Range (yr)	Current Interval (yr)	MFI (yr)
10	Psme/Caru	4	1766-1870	4	17-44	119	35
31	Psme/Syal	2	1534-1870	10	14-85	119	37
33	Psme/Caru	1	1756-1940	3	70-114	49	92
Area 4-stand Cluster:		8	1534-1988	15	4-89	1	32

Table 3. Fire occurrence data (MAFIs based on stand initiation years) for lodgepole pine stands occurring on moist and dry sites.

Stand No.	Aspect	Elev. (m)	Fire Intervals[1] (yr) Partial Std. Replacing Fire	Total Std. Replacing Fire
		DRY SITES (e.g. Abla/Vasc H.T.):		
20	SE	2070	-	232
22	SE	2400	-	232
24	SE	2300	-	183
25	SE	2360	-	204
26	SE	2300	-	76
27	E	2389	21	183
28	S	2365	51	153
29	S	2500	79	153
35	W	2097	55	208
36	W	2100	56	153
		MOIST SITES (e.g. Abla/Vagl H.T.):		
1	NW	2179	-	195+
3	NW	2499	-	233+
11	N	2268	-	233+
12	NW	2316	-	162+
40	N	2414	-	153
41	N	2292	-	232
42	N	2463	-	251
43	N	2268	-	153

MAFIs for Stand Replacing Fires:

	Partial S.R.	Total S.R
Dry Sites:	52	178
(Yr.Range):	(21-79)	(76-232)
Moist Sites:	-	202
(Yr.Range):	-	(153-233+)

[1] "+" denotes yrs. since last fire (current stand age).